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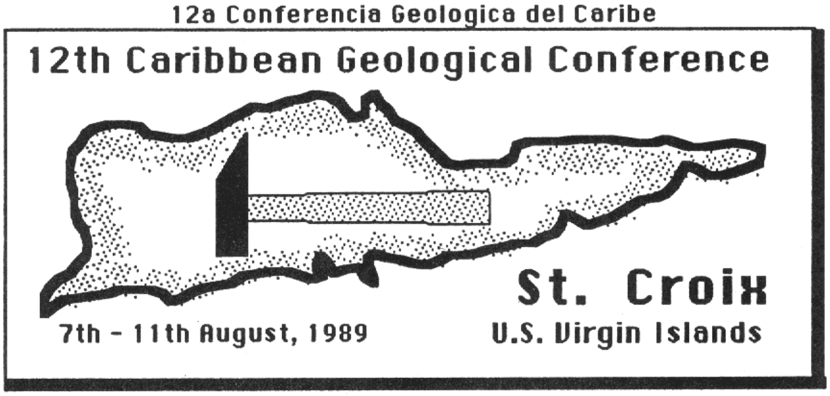

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TECTONOSTRATIGRAPHY OF THE SAN FRANCISCO RIDGE AREA IN THE NORTHEASTERN CIBAO VALLEY, DOMINICAN REPUBLIC.

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ABSTRACT

Neogene strata exposed along the San Francisco ridge (SFR) in northeastern Hispaniola record the tectonostratigraphic evolution of a former marine basin, the present day Cibao Valley, which is adjacent to a now uplifted subduction complex, the Cordillera Septentrional. Deep-water calciclastic strata of Miocene age are unconformably overlain by shallow-marine carbonate strata of early Pliocene age. These strata are in turn unconformably overlain by mainly fluvial channel deposits of later Pliocene age or younger.

In the SFR, Miocene strata are folded and faulted which indicates that uplift and deformation occurred since latest Miocene time. The intense deformational event ceased by early Pliocene time as indicated by the much less deformed Pliocene strata. A Pliocene or later deformational event resulted in the present relief of the SFR as evidenced by the broad warping of the Pliocene strata over the SFR.

The topographic expression of the SFR dies out west of Samana Bay, yet this structure, by correlation with seismic data, appears to continue to the east offshore beneath the bay.

INTRODUCTION

The area of study forms an irregular quadrangle of 300 km located in the eastern Cibao Valley of the northeastern Dominican Republic (Fig. 1). Much of the terrain lies along a topographic high up to 400 m in elevation that is dissected by deep river valleys which give rise to the hilly landscape and includes a narrow strip of the southern part of the Cordillera Septentrional. This ridge is part of the northern slope of the Cibao Valley which is bounded to the north by the Septentrional fault system. Because of its location near the city of San Francisco de Macoris this ridge was called the " San Francisco Ridge" (SFR) by Winslow and McCann 1985. This study covers the Western half of the SFR.

The purpose of this study is to provide brief descriptions of the formations informally defined by the author for 300-600 m of exposed Neogene strata. The stratigraphic and structural framework are presented on a 1:50,000 scale map and offer an interpretation of the tectonostratigraphic evolution of the area.

The field data of this study are correlated with the seismic profile SS' (Edgar and Rodriguez, 1990), through Samana Bay located 55 km east of study area (Fig. 1B).

TECTONIC SETTING

The SFR is part of the northern flank of an uplifted marine basin, the Cibao Valley, and is separated from the uplifted subduction complex of the Cordillera Septentrional by the Septentrional fault system (Bowin, 1966; Bowin and Nagle, 1980; Nagle, 1971, 1974; Nagle et al., 1979). This complex was formed by the southward subduction of the North American Plate beneath the Caribbean Plate during Cretaceous to about late Eocene time (Bowin, 1975; Draper and Lewis, 1982; Rosencrantz et al., 1988). By late Eocene time, plate motion changed so that the Caribbean Plate began to move eastward with respect to the North and South American Plates (Burke et al., 1984; Duncan and Hargraves, 1984; Joyce, 1990; Malfait and Dinkelman, 1972; Mattson, 1984; Ross et al., 1986; Sykes et al., 1983; see Fig. 1A). Many authors suggest that the collision of the Bahama Bank, a buoyant feature on the North American Plate, caused a slowing of lateral motion and contributed to the uplift of the subduction complex (Dolan et al., 1990; McCann and Sykes, 1984; Mann et al., 1984; Nagle, 1974). By Neogene time, the northern margin of the Caribbean Plate in northern Hispaniola became a tranpressional boundary caused by local convergence at a restraining bend along the east-west Septentrional strike-slip fault system (De Zoeten and Mann, 1990; Evans, 1990; Lewis, 1980; Mann, et al., 1984; Redmond, 1980).

LITHOSTRATIGRAPHY

Lithostratigraphic data were principally collected by traverses of rivers which parallel and cut across the strike of the rock units. These data were combined with aerial photo interpretations to construct the geologic map (Fig. 2) and the cross-sections (Fig. 3). Field descriptions, measured sections, petrographic and micropaleontological data (Fig. 4; Appendix A) were used to determine the stratigraphic framework of the SFR which is expressed in the composite columnar section shown on Fig. 5.

Within the area of study, seven informal formations have been defined (Figs. 2 and 5). Of these, the El Firme and Cinta Negra formations (both named and described by Guglielmo, 1988) are located to the east of the study area and in a structurally complex area northwest of the SFR. At this time their stratigraphic relationships are incompletely understood.

Of the remaining formations, the Arroyon, Los Cafes, and Castillo formations (named and described by Guglielmo, 1988 and Nadai 1987), consist of a conformable

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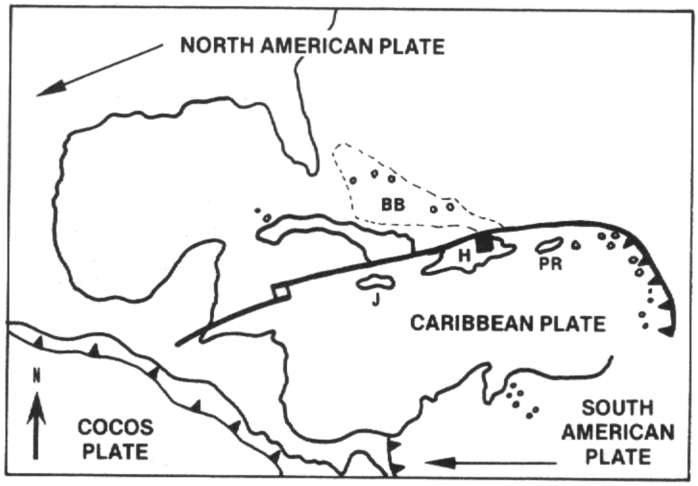

Figure 1A. Tectonic setting of study area. Area of Fig. 1B is represented by box; H=Hispaniola, BB=Bahama Bank, J=Jamaica, PR=Puerto Rico. Arrows indicate plate motions in reference to the Galapagos hot spot frame (Duncan and Hargraves, 1984).

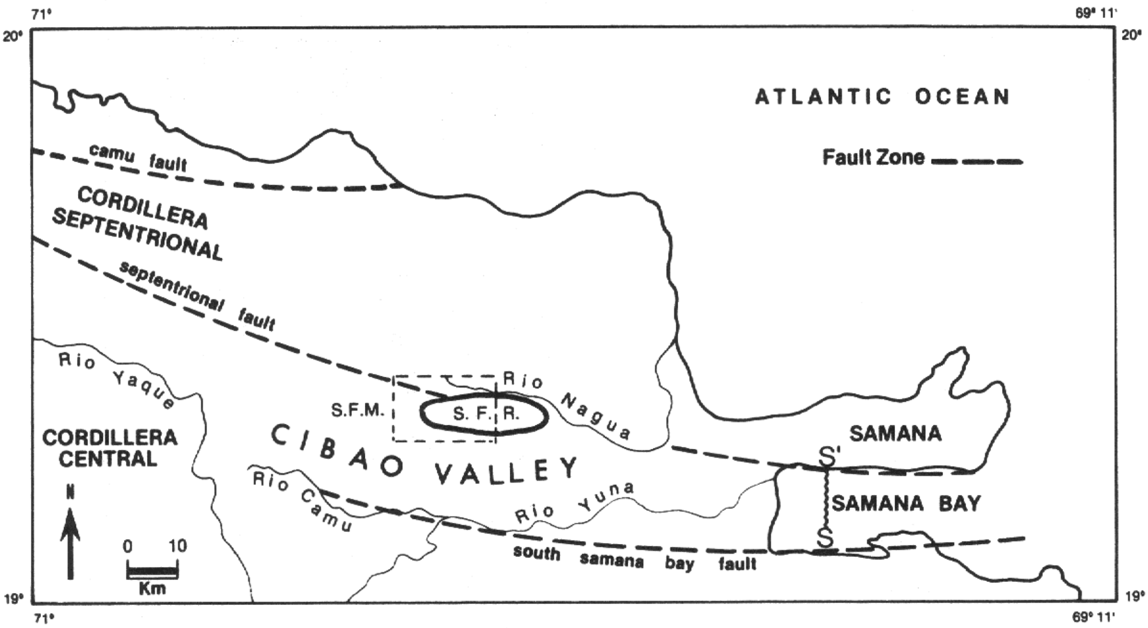

Figure 1B. Northeastern Dominican Republic. Dashed outline indicates study area SFM = San Francisco De Macoris; SFR=San Francisco Ridge.

Figure 1C. Photograph of the San Francisco Ridge. View is southward.

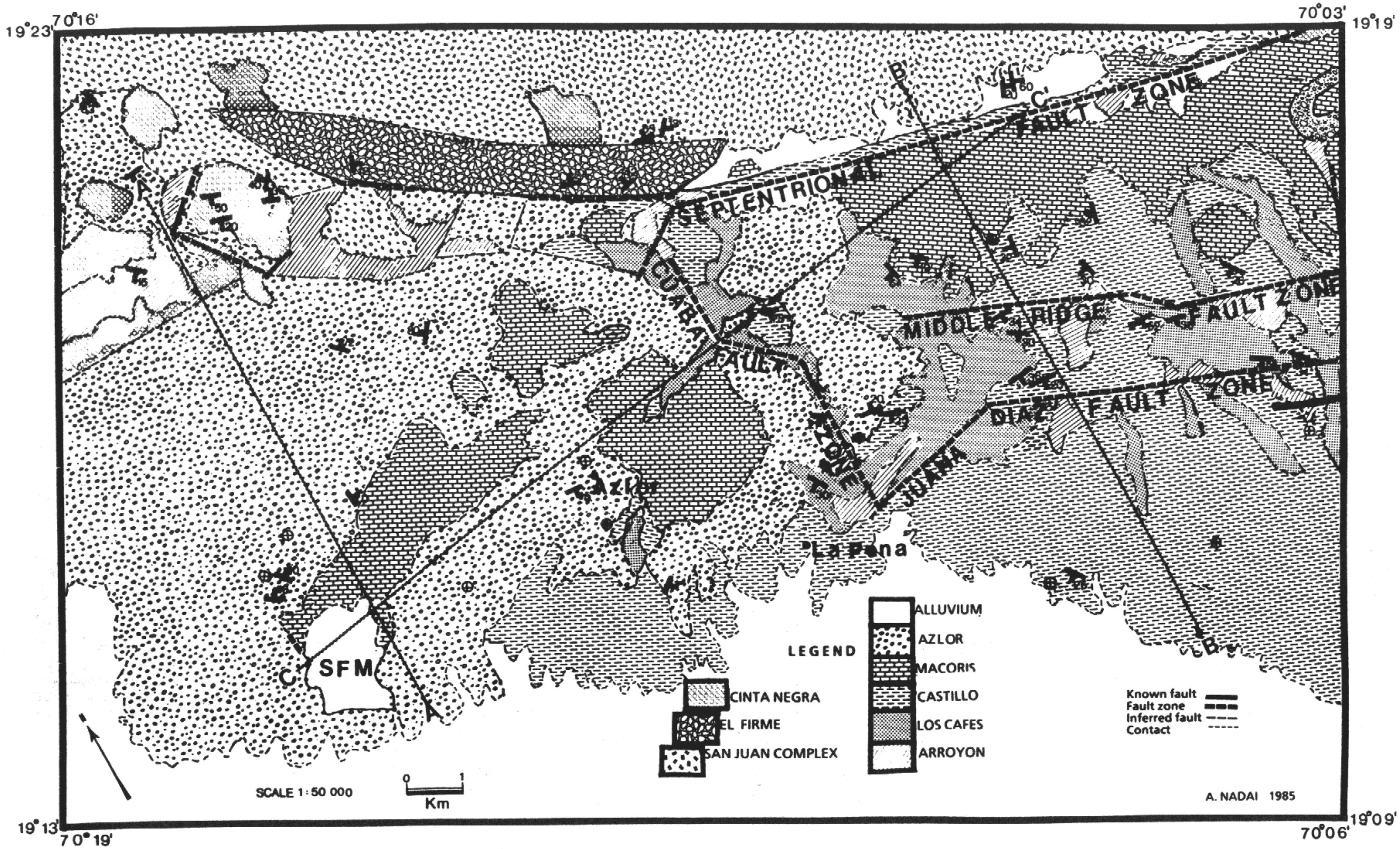

Figure 2. Interpretative geologic map of the western half of the SFR.

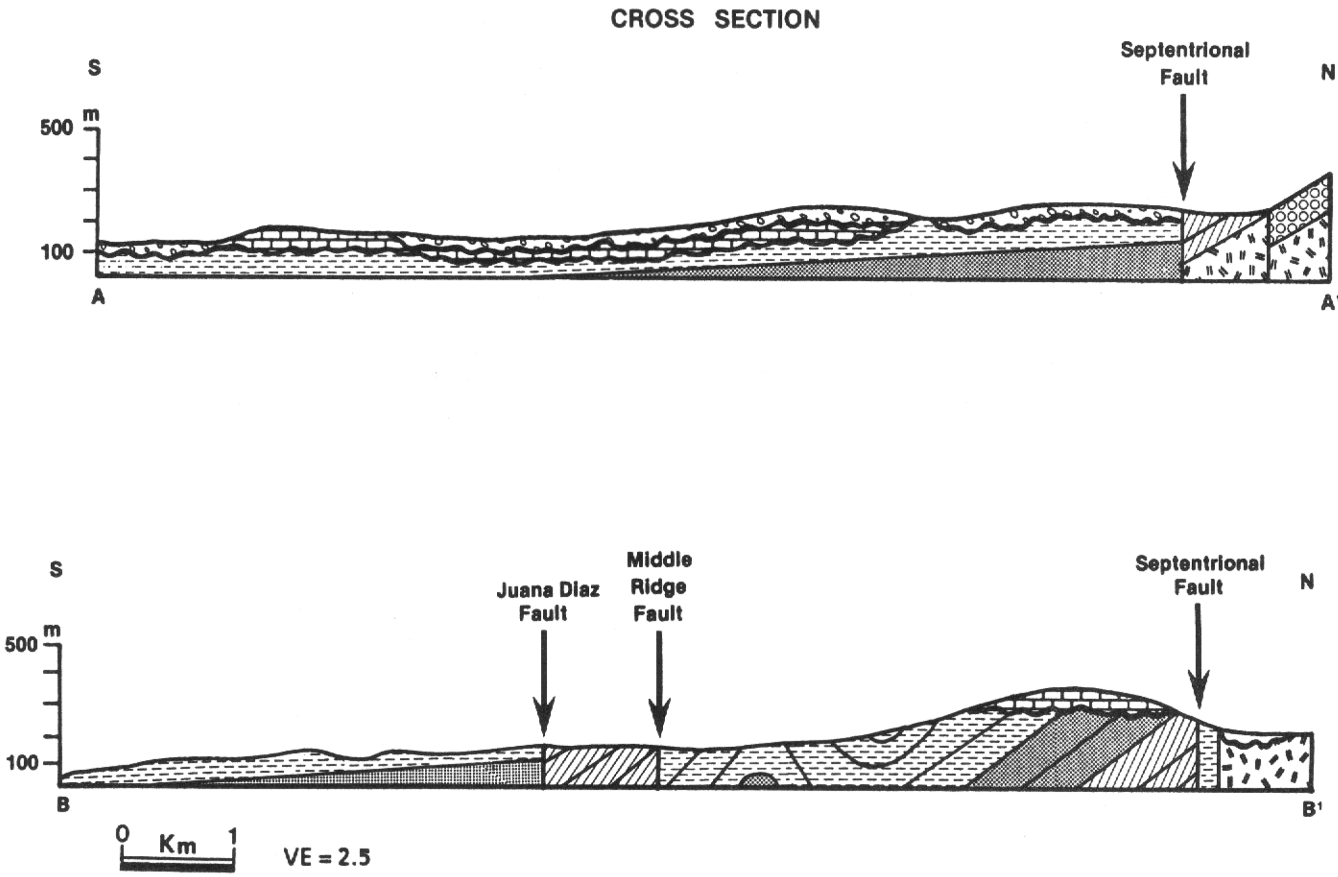

Figure 3. Cross-sections AA' and BB' cut through the entire width of the SFR. See Fig. 2 for line of section. Symbols same as in Figs. 2 and 5.

sequence of deep-water calciclastics. They are unconformably overlain by the Macoris formation (named and described by Nadai, 1987), which is a shallow-marine carbonate. The Macoris is in turn unconformably overlain by the Azlor formation (named and described by Nadai, 1987), which consists mainly of fluvial channel deposits (Fig. 5).

The oldest rocks exposed in the northern part of the study area occur in the Cordillera Septentrional and form the Rio San Juan Complex which was mapped and described by Bowin and Nagle (1982), Draper and Nagle (1985, 1988) and Draper and Lewis (1990). It consists of a gneissic unit, the Cuaba Amphibolite, and a series of banded gabbros, diorites, and ultramafic cumulites called the Rio Boba Intrusive Suite. These units range in age from middle-late Cretaceous to Paleocene (Fig. 2).

The El Firme formation, consists of more than several hundred meters of polylithic diamictite which contains a variety of volcanic, plutonic, metamorphic, and sedimentary rock clasts. All clast types are angular to subangular and range in size from 1 to 30 cm. The matrix consists of sand to silt-sized siliciclastics with minor amounts of carbonate and glauconite grains. The unit is massive with little evidence of stratification or grading. The El Firme formation is still being studied and at this time no firm conclusion can be reached as to the environment of deposition or precise age, although a post-Cretaceous to pre-Miocene age is most likely. This formation crops out along the Septentrional fault and in the Cordillera Septentrional (Fig. 2).

The Cinta Negra formation, is estimated to be more than 300 m thick. It is a massive reefal limestone that has been partially dolomitized and recrystallized. The presence of Montastraea annularis suggests an age of Miocene or younger and indicates that deposition occurred in a shallow-marine environment (J. Wells, pers. comm., 1986). The Cinta Negra formation crops out along the western section of the Nagua River in the Septentrdional fault zone and in the Cordillera Septentrional (Fig. 2).

The Arroyon formation, and is more than 100 m thick. It consists of interbedded calcarenites, calcisiltites, and calcilutites (Fig. 6). Beds range in thickness from 10 to 30 cm and consist of complete or incomplete Bouma sequences. The stratigraphic position as well as the presence of Globigerinoides of the trilobus group date these units as Miocene (R. Liska, pers. comm., 1986). This formation crops out in the SFR and along the Septentrional fault and is conformably

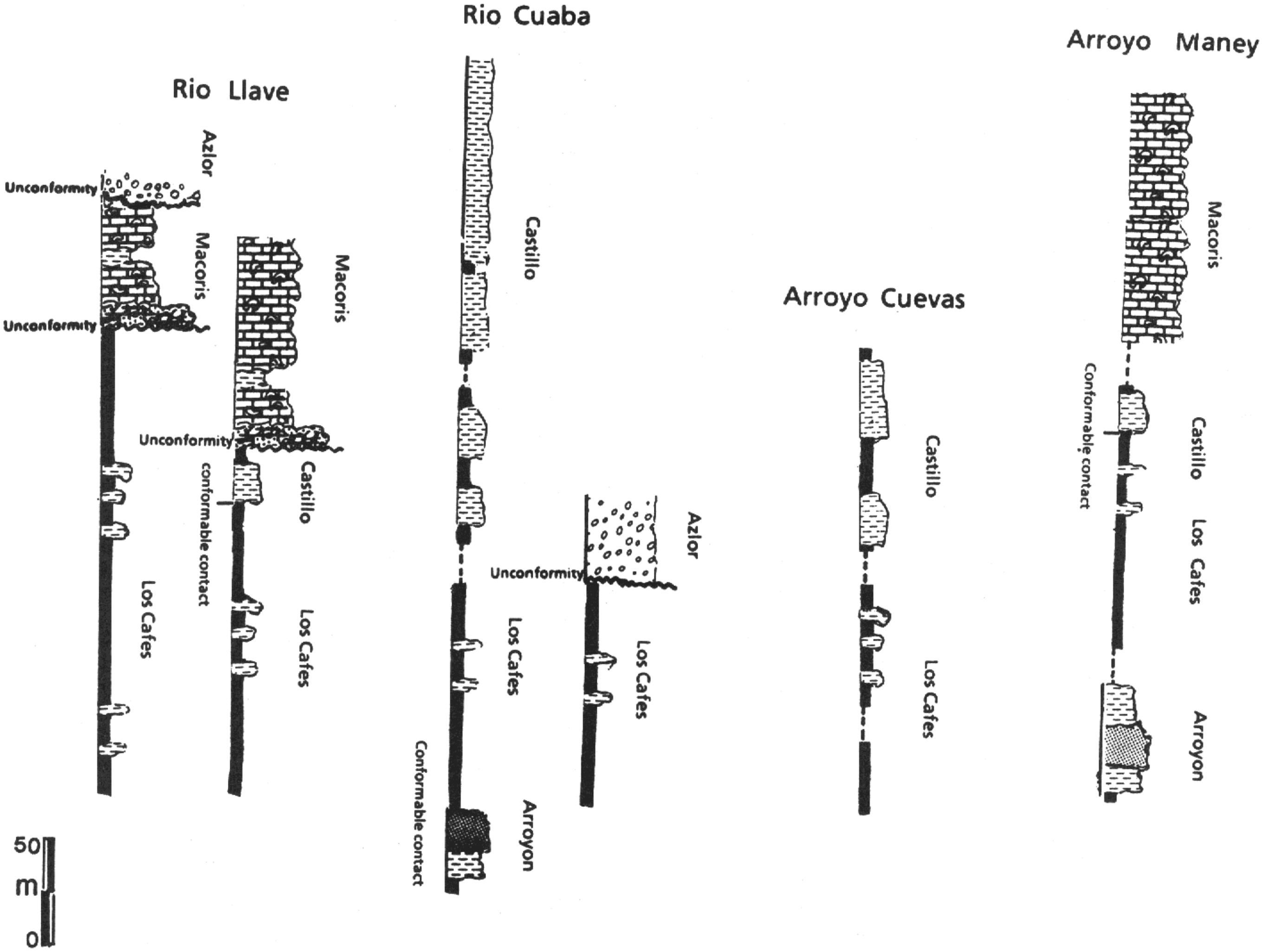

Figure 4. Columnar sections of four river traverses in the study area. a) Rio LLave, b) Rio Cuaba, c) Arroyo Cuevas, d) Arroyo Maney. See Fig. 10 for localities. See Figs. 2 and 5 for descriptions of lithologic symbols.

overlain by the Los Cafes formation (Figs. 2 and 5).

The Los Cafes formation, varies from 100 to 200 m in thickness. It consists of gray to green calcilutite. Conchoidal fracturing on weathered surfaces gives the characteristic texture of this formation. Locally, 2 to 3 cm thick beds of laterally continuous calcisiltite break the monotony of this unit's massive appearance. Based on its stratigraphic position, the Los Cafes formation is tentatively considered to be of Miocene age. This formation crops out along the axis of the SFR and is conformably overlain by the Castillo formation (Figs. 2 and 5).

The Castillo formation, ranges from 50 to 150 m in thickness. It consists primarily of interbedded, bioclastic calcisiltites and calcilutites. Beds vary in thickness from 20 to 40 cm for the calcisiltites and 15 to 30 cm for the calcilutites. In places, bedding is indiscernible and the formation appears massive. Based on the presence of a planktonic foraminiferal assemblage (Globigerinoides, Orbulina universa, Sphaeroidinellopsis penediscens, Globorotalia margaritae, Globigerina nepentes, Neogloquadrina humerosa) the Castillo formation is dated as late Miocene (Zone N-17 fide Blow: 7.1 to 5.4 Ma; R. Liska and E. Robinson, pers. comm., 1986; Saunders et al., 1986). The Castillo formation is unconformably overlain by either the Macoris formation or the Azlor formation (Fig. 7). In southernmost exposures, it is unconformably draped by alluvium. It crops out along the southern flank of the SFR and the Nagua River (Fig. 2).

The Macoris formation is named for exposures near the city of San Francisco de Macoris (Fig. 2) and ranges from 50 to 150 m in thickness. It is a rough-surfaced, grayish-yellow, vuggy, fossiliferous limestone that contains many calcarenite and calcisiltite layers. Its rough texture is due to the presence of the cigar-shaped fossil, Kuphus incrassatus (Vokes, 1972) which can be up to 20 cm long and have a diameter ranging from 1 to 4 cm (Fig. 8). These limestones are partially

Figure 6. Arroyon formation. Bedded calcarenite, calcisiltite and calcilutite; interpreted as a deposit of deep-water turbidity currents. This exposure was taken at the northwestern end of the SFR and the fault lies in the Septentrional Fault Zone area.

recrystallized and in places dolomitized and where weathered become loose and chalky. The Macoris formation can be bedded or massive. Where bedded, the layers rich with Kuphus are 30 to 40 cm thick and alternate with silty limestone layers that are 10 to 20 cm thick. The massive appearance of the Macoris formation occurs where Kuphus-rich beds thicken upward to form a massive Kuphus coquina that locally contains an oolitic facies.

The base of the Macoris formation is interpreted as an erosive unconformity (Fig. 7). This interpretation is based on the observations that: (1) The basal beds of the Macoris formation display erosive channeling and contain clasts of the Castillo and Los Cafes formations; (2) along the flanks and axis of the SFR, the flat to moderately tilted Macoris strata overlie more steeply dipping and faulted beds of the underlying formations (Fig. 3); and (3) the abrupt change to shallow-marine carbonates (Macoris formation) from deep-water calciclastics (Arroyon, Los Cafes, and Castillo formations) is incompatible. Because the Macoris formation unconformably overlies the late Miocene Castillo formation, it is most likely early (?) Pliocene in age. The Macoris formation is unconformably overlain by the Azlor formation (Fig. 5).

The Azlor formation is named for exposures near the village of Azlor (Fig. 2) and ranges in thickness from 5 to 60 m. It is a loose to semi-indurated, poorly-sorted polylithic diamictite composed of a variety of sedimentary, igneous, and metamorphic rock clasts. The matrix consists of red sand

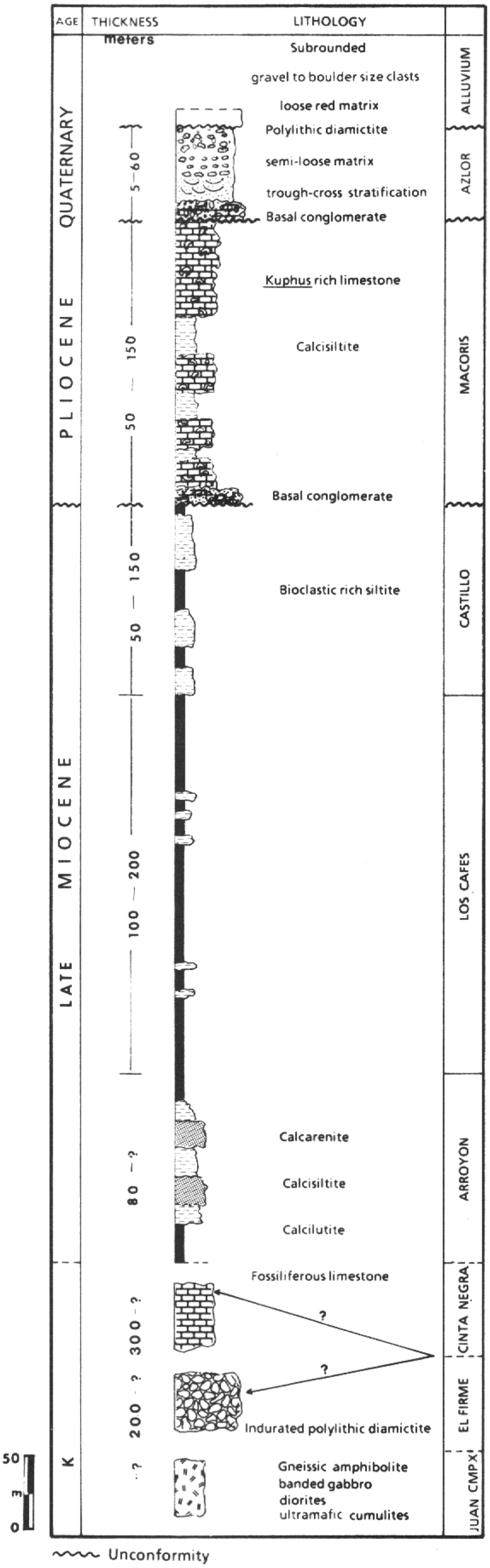

Figure 5. Composite columnar sections for the western SFR area, north slope of Cibao Valley, Dominican Republic.

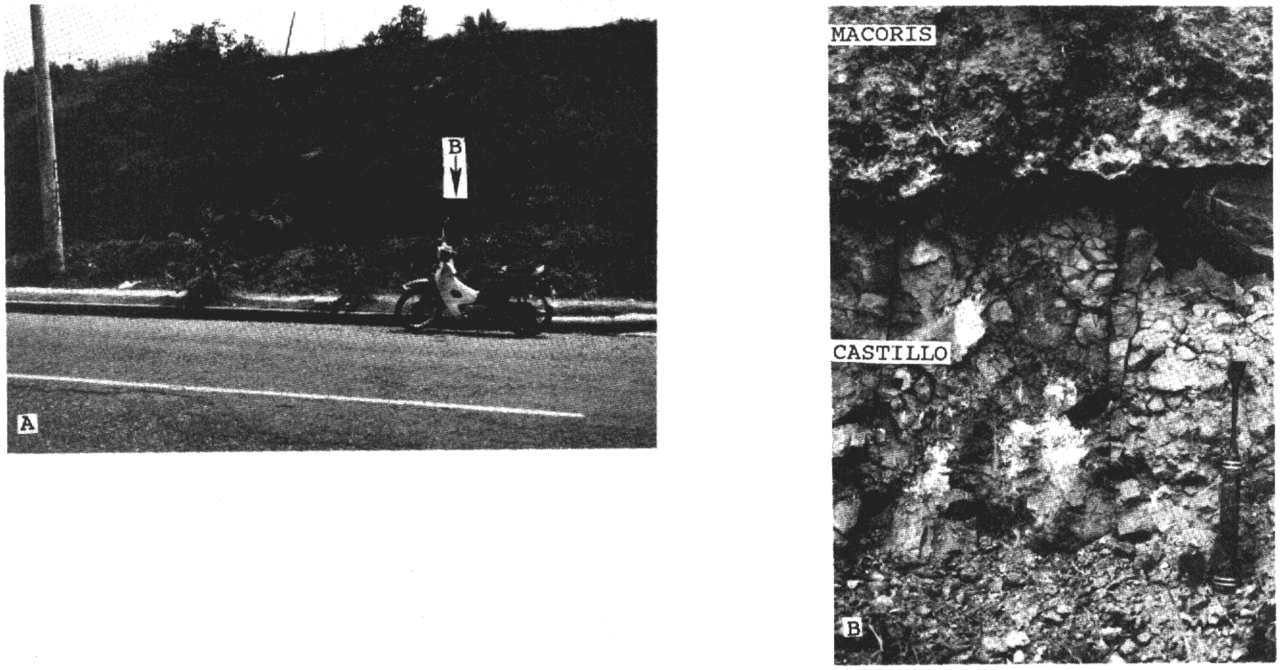

Figure 7. Unconformity between the Castillo and Macoris formations. The former is interpreted as a deep-water calciclastic deposit and the latter as a shallow-marine carbonate. A. View of the outcrop. B. Boxed area shown in A.

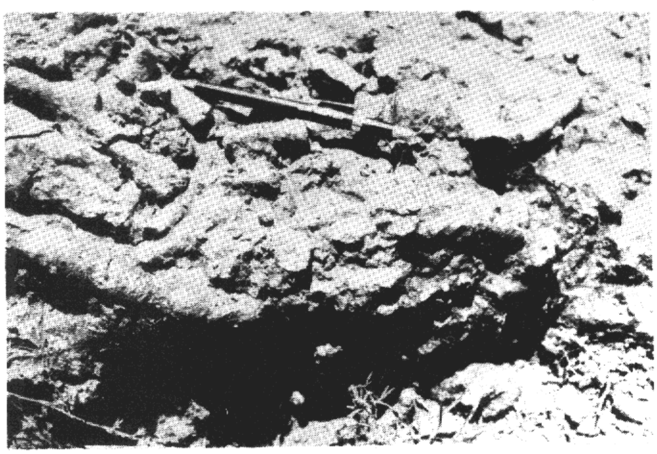

Figure 8. Macoris formation, a Kuphus-rich limestone.

Figure 9. Azlor formation, a semi-indurated, polylithic diamictate interpreted as a fluvial channel deposit.

and silt. The Azlor formation is poorly bedded to massive and displays a range of sedimentary structures from disorganized fabric to trough cross-bedding and clast imbrication (Fig. 9). Because of its stratigraphic position, the Azlor formation can be no older than early Pliocene. This formation is interpreted as a fluvial deposit. The basal erosive contact is in the form of channels that have carved into the older formations. The Azlor covers most of the western half of the study area.

STRUCTURES

The outstanding structural features which characterize the study area of the San Francisco Ridge are five faults (Fig. 2): the Septentrional and Juana Diaz faults that run along its entire length; the Cuaba fault which crosses the ridge to the east of San Francisco de Macoris; the Middle Ridge fault which cuts the ridge lengthwise in an E-W direction; and an unnamed fault which trends N-S through the middle of the ridge.

The Septentrional fault was described by Bowin in 1966 and mapped by Blesch in 1966; but it was recognized in unpublished reports since 1943 (De Zoeten and Mann, (1990). The Juana Diaz fault was identified in the field by Guglielmo et al., (1986), the Cuaba fault and the Middle Ridge fault were identified and mapped in this study and the unnamed fault was observed in the field by Winslow (pers. comm., 1987); the latter two faults need further investigations. The change in drainage patterns, field mapping of structurally deformed formations and tectonized zones, and lineaments observed on aerial photos on a scale of 1:40000 and on SEASAT-SAR images, are used collectively as evidence for the existence of these faults (Fig. 10). These faults cut across the topography at high angles, but their displacements were not established. The presence of triangular facets on the southern flanks of the Cordillera Septentrional with their bases parallel to the fault trace suggests a dip-slip component to the mainly left-lateral strike-slip displacement observed west of this study area (Eberle et al. 1980; Mann et al. 1984; Winslow and McCann, 1985; Fig. 11). The displacement of the Septentrional fault separates the Cordillera Septentrional from the Cibao Valley. The Juana Diaz and Cuaba faults separate the intensely deformed Miocene formations of the SFR (Arroyon, Los Cafes and Castillo) from the much less deformed Pliocene or younger formations of the Cibao Valley (Macoris and Azlor).

The trend of the three subparallel, E-W faults and the SFR structure ranges between N75W to N85W. In the study area, none of the five faults appear to cut across the Pliocene or younger formations (Macoris and Azlor; Fig. 3).

CORRELATIONS

Cross-section BB', across the SFR structure matches remarkably well with the N-S seismic profile SS'of the Samana Bay (Figs. 12 and 13). The Septentrional, Middle Ridge and Juana Diaz faults align with the three steep south-dipping faults offshore with a slight change in strike from WNW to approximatly E-W, a trend previously observed by Mann et al. (1984). The topographic high of the SFR aligns with the subsurface uplifted basement. Both profiles BB' and SS' show the deformed Miocene strata to be overlain by the relatively nondeformed Pliocene or younger strata and separated from it by an unconformity. The Juana Diaz and Middle Ridge faults and their inferred extensions along the seismic profile do not cut across Pliocene formations. However, in the seismic profile, the inferred extension of the Septentrional fault does cut across the Pliocene or younger formations. This agrees with the field observations west (Winslow and Mc Cann, 1985) and east (Guglielmo and Winslow, 1986) of this study area which also have shown that the Septentrional fault cuts the Pliocene or younger formations.

The proposed correlation of the field data in the west with seismic interpretations in the east suggests that the SFR, which is expressed topographically in the study area, continues eastward as a structure in the subsurface and offshore beneath Samana Bay (Fig. 13).

The Miocene-Pliocene carbonate strata identified in this study are coeval with the Villa Trina Formation located in the Cordillera Septentrional, which lies unconformably (Vaughan et al. 1921) and in places conformably (De Zoeten and Mann, in prep.) over the 4000 m thick deep-marine siliciclastics, the Altamira and La Toca Formation of upper Eocene to middle Miocene age.

TECTONOSTRATIGRAPHIC EVOLUTION

The lateral and vertical facies characteristics as well as the faunal assemblages indicate a relatively deep-water marine depositional environment for the Miocene strata (Arroyon, Los Cafes, and Castillo formations). During latest Miocene time, this deep marine basin was uplifted and deformed. The deformational event must have ceased or diminished by Pliocene time because the folded and highly faulted Miocene strata exposed along the SFR are erosionally truncated and unconformably overlain by the much less deformed Macoris formation (Fig. 3). The interpretation of the Macoris as a shallow-marine carbonate and the observation that it is relatively thin (<200 m) indicate that tectonism was minimal and that the basin maintained shallow-marine conditions. The area became subaerial during post-Macoris time (mid-late Pliocene ?) as evidenced by the unconformably overlying fluvial channel deposits of the Azlor formation.

Both unconformities (base of the Macoris formation and base of the Azlor formation) rise topographically along the SFR, which suggests a post-Azlor warping (Fig. 14). This event is responsible for the topographic expression of the SFR. The age and nature (block rotation, fault reactivation, compressional folding, etc.) of this latest deformation, however, remain to be determined.

It does appear though, that tectonism dramatically overprinted the relative global eustatic sea level changes proposed by Vail, Mitchum and Thompson (1977).

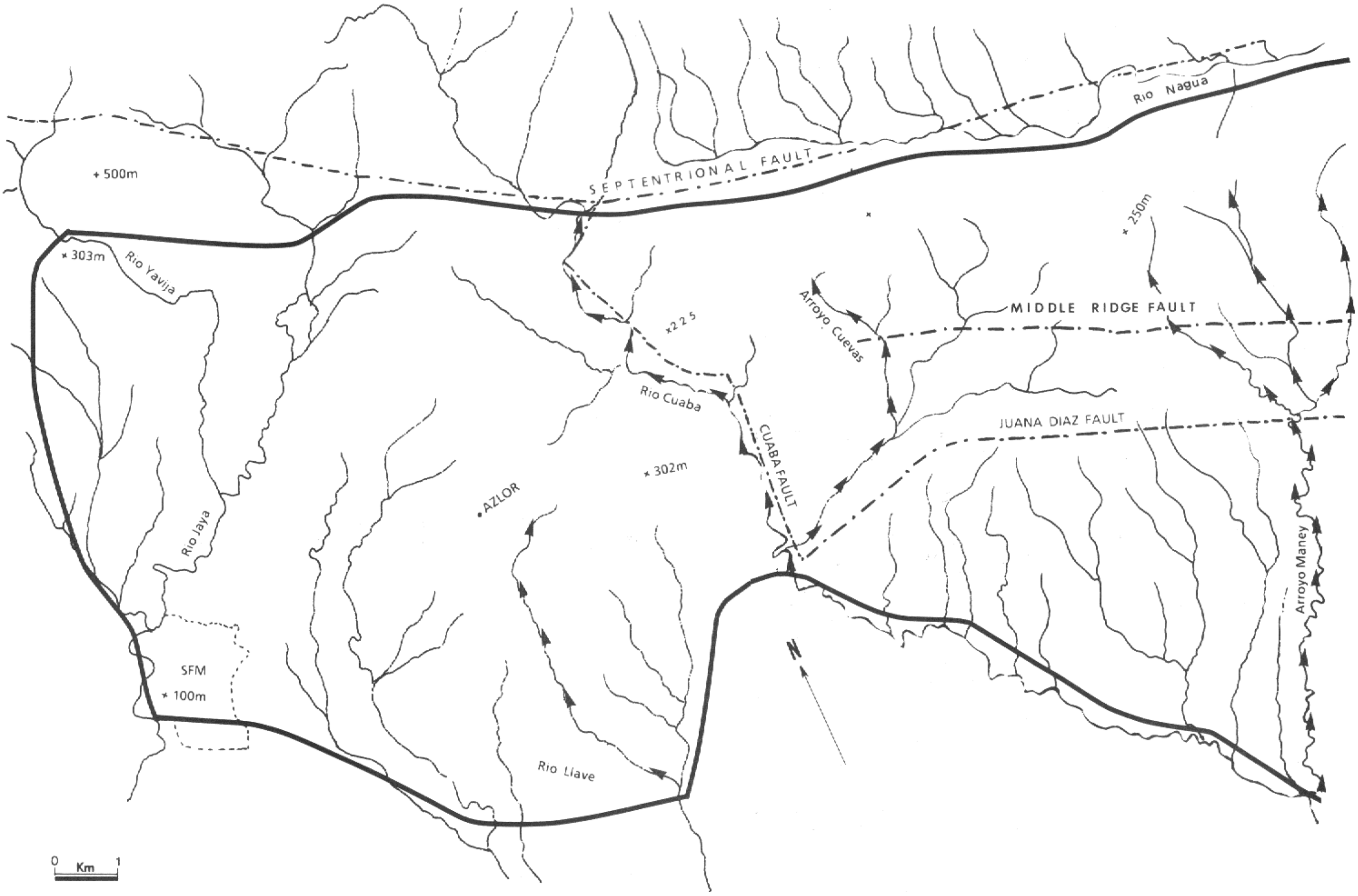

Figure 10. Drainage patterns and faults along the western SFR region. The solid line outlines the area of the western half of the SFR. The arrow points indicate the river traverses interpreted in Fig. 4.

Figure 11. Cordillera Septentrional with faceted spurs, view northward from the Cibao Valley.

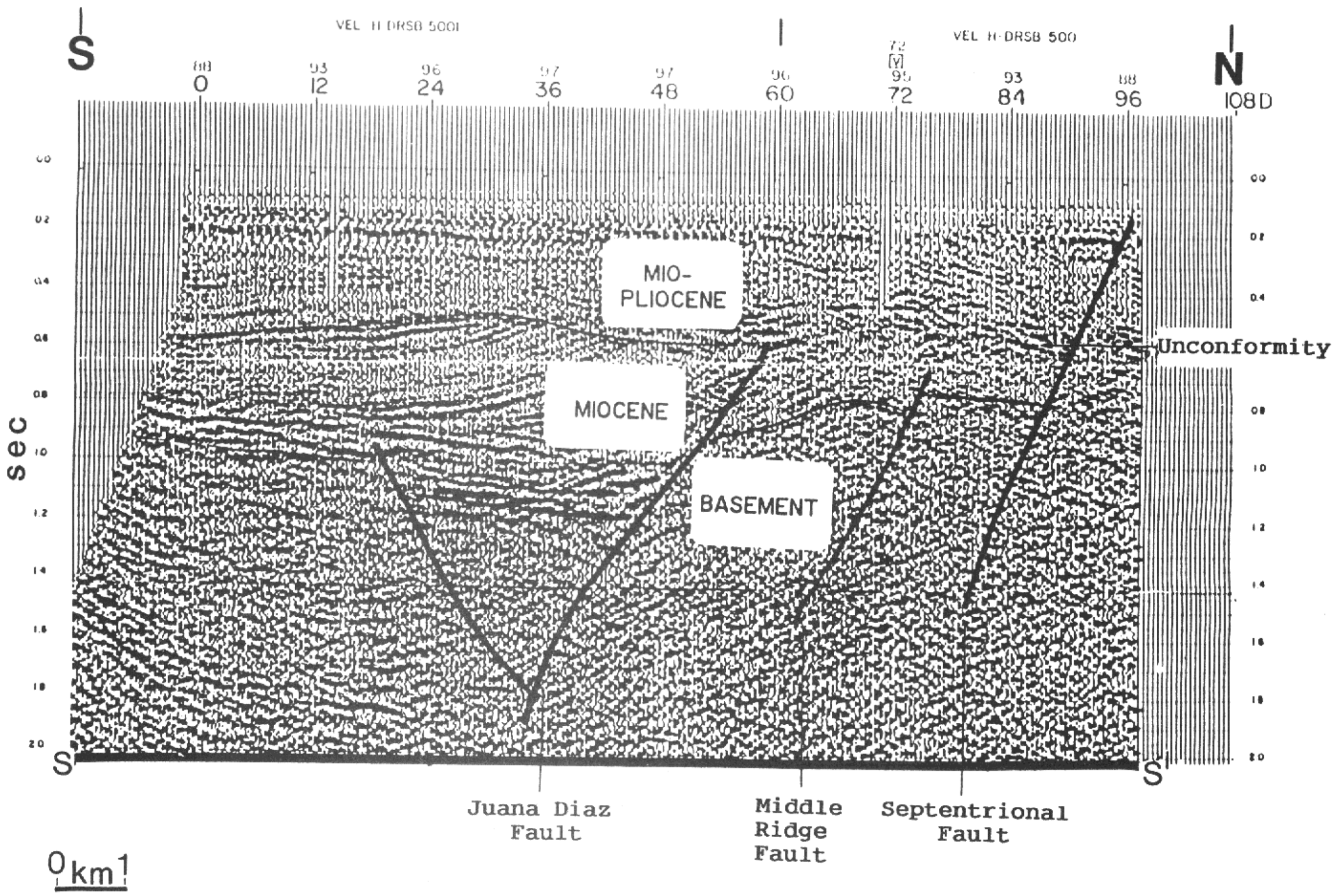

Figure 12. N-S seismic profile through Samana Bay with stratigraphic interpretation by Edgar and Rodriguez, (1990). Location of SS' profile shown in Fig. 1B.

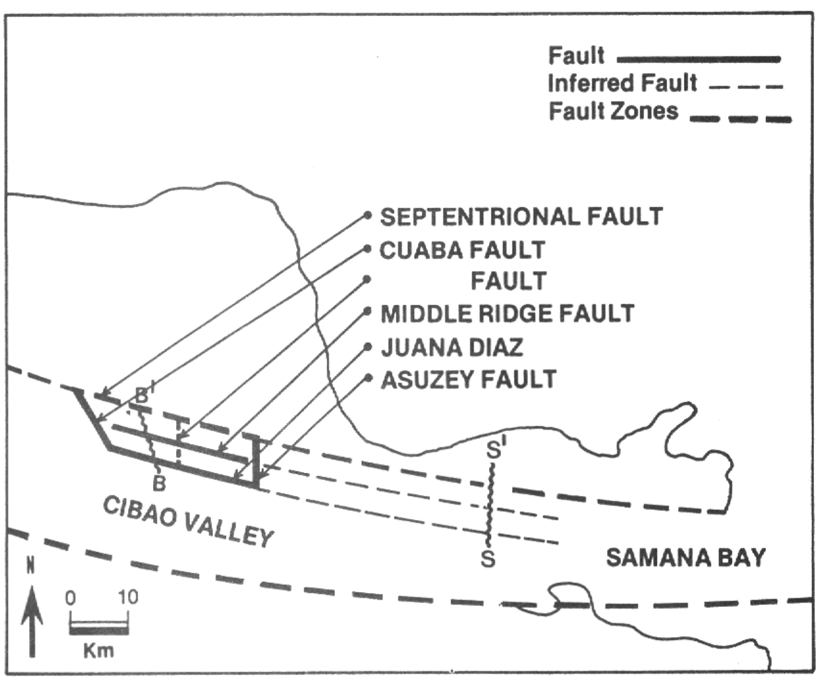

Figure 13. Suggested correlation of the faults of the SFR with the faults of the Samana Bay seismic profile. The Asuzey fault is east of the study area and is described by Guglielmo and Winslow (1988).

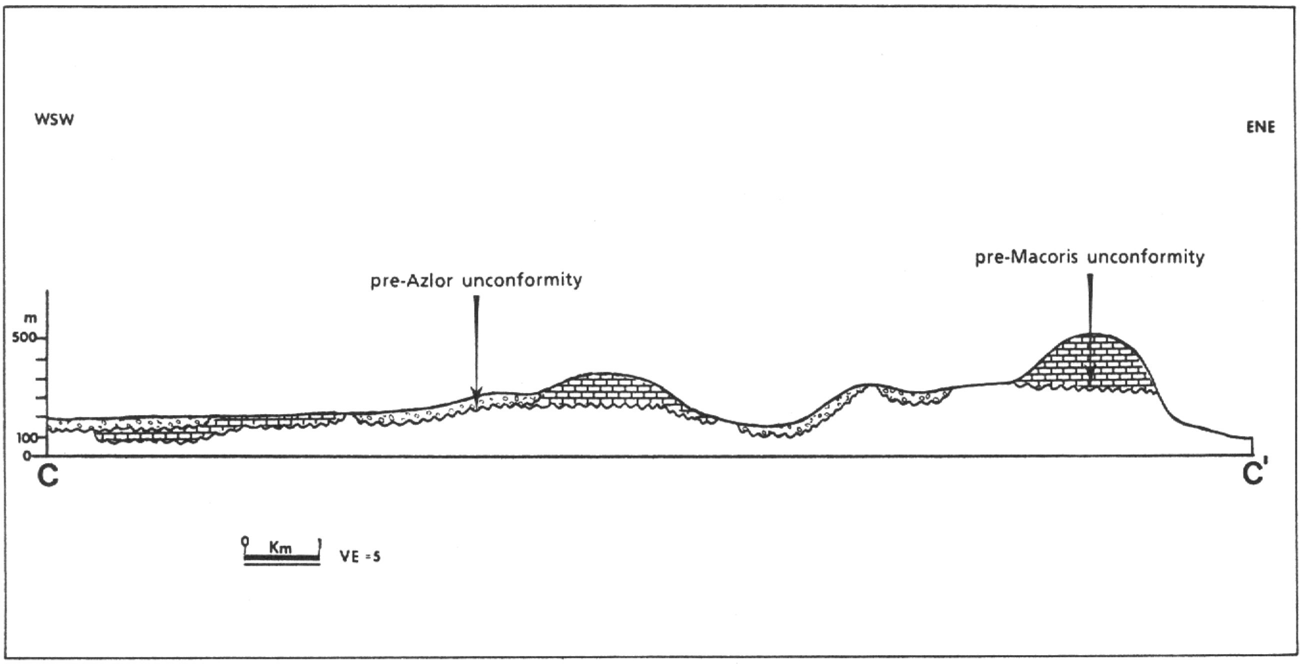

Figure 14. Cross-section showing the topographic variation of the Pliocene or younger unconformities. Lithologic symbols the same as in Figs. 2 and 5.

CONCLUSION

The Neogene strata exposed along the San Francisco Ridge on the northern slope of the Cibao Valley, which is part of the uplifted subduction complex of northeastern Hispaniola, have been divided into seven formations. These strata reveal the following tectonostratigraphic evolution:

1) During the Miocene, this area was a relatively deep-marine basin as evidenced by a conformable sequence of turbidite strata. 2) A late Miocene tectonic event deformed those strata in the SFR. 3) During the early Pliocene, the deformational event ended and shallow-marine carbonates were unconformably deposited on the deformed Miocene strata. 4) The basin subsequently became subaerial as indicated by a series of unconformably overlying fluvial channel deposits. 5) The Pliocene or later uplift is ultimately responsible for the SFR relief. This is revealed by the varying topographic location off and on the SFR of the two Pliocene or later unconformities. The mechanisms of the pre-Pliocene uplift of the deep-marine Cibao Basin and the later uplift of the SFR have not been identified. The topographic expression of the SFR dies out about 10 km west of Samana Bay yet this structure, by correlation with seismic data, appears to continue to the east offshore beneath the bay.

ACKNOWLEDGEMENTS

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APPENDIX A

Age and paleobathymetry of the SFR formations:

E l F i r m e f o r m a t i o n (Guglielmo and Winslow 1986).
Bathymetry: shallow water benthic and planktic foraminifera and calcareous algae. (C.B. Schreiber, pers. comm., 1986).

A r r o y o n f o r m a t i o n (poor preservation of fossils, reworked or diagenetically altered)
Age: based on one _Globigerinoides_ of the _trilobus_ group, dates the fauna as Miocene or younger (R. Liska, pers. comm., 1986).
Bathymetry: middle shelf environment of deposition (R. Liska, pers. comm., 1986).
Indeterminate benthic fauna: Uvigerinids, Cassidulinids, Buliminids, Miliolids and Anomalinids.

L o s C a f e s f o r m a t i o n (probably equivalent to the Castillo formation).

C a s t i l l o f o r m a t i o n
Age: 7.1-5.4, my bp, late Miocene, (Zone N-17 _fide_ Blow), suggested from planktic assemblage.
(R. Liska and E. Robinson pers. comm.,1986).

Bathymetry: open marine shelf environmnent 200 m depth or deeper, depends on location as suggested from benthic assemblage.
Planktic Foraminifera: Globigerinoides ? canimarensis, G. obliquus, G. quadrilobatus, G. trilobus, Orbulina universa, Sphaeroidinellopsis penedehiscens, Globorotalia cf margaritae, G.scitula, G. pseudomiocenica, Globigerina nepenthes, G. eamesi, Neogloboquadrina humerosa.
Benthic Foraminifera: Nodosaria spp, Siphonina pulchra Cibicidoides, Hoeglundina elegans, Planulina ariminensis, P. cf foveolata, Pullenia bulloides, Melonis barleeanus, Valvulineria sp., Sphaeroidina bulloides, Discorbis sp., Uvigerina peregrina, Globocassidulina subglobosa.

Macoris formation
Age: Middle Miocene or younger, suggested by the foraminifera assemblages (R. Liska and E. Robinson, pers. comm., 1986).
Bathymetry: shelfal environments, suggested by benthic foraminifera (R. Liska, pers. comm., 1986), intertidal suggested by various bioclasts analysed in thin sections coralline algae, Halimeda (0.5 to 10 m deep), Kuphus (intertidal), Miliolids (C.B. Schreiber, pers. comm., 1986).
Planktic Foraminifera: Orbulina spp., Globigerinoides trilobus trilobus, Globigerinoides trilobus immaturus, Hastigerina siphonifera.
Benthic Foraminifera: Heterostegina spp., Amphistegina spp.

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